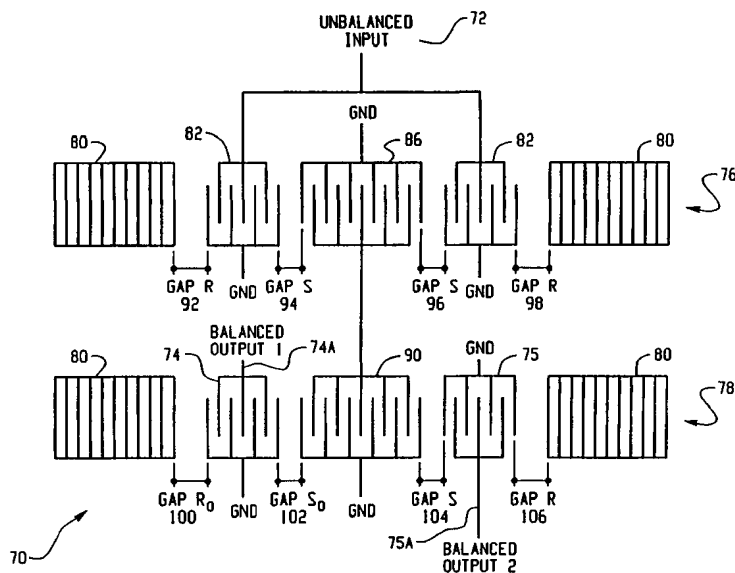




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**(54) Title:** DIFFERENTIAL SURFACE ACOUSTIC WAVE FILTER HAVING BALANCED OUTPUTS



**(57) Abstract**

A differential SAW filter having a cascaded structure includes an input SAW stage and an output SAW stage. The two SAW stages are configured so that the distance of travel of the surface acoustic waves from a single unbalanced input of the input stage to the dual balanced outputs of the output stage is electrically equidistant, thus resulting in a balanced differential output. The input stage includes a single unbalanced input coupled to a pair of outer IDTs, which both launch a surface acoustic wave to a single input stage inner IDT. The input stage inner IDT connects to the input IDT of the output SAW stage, which launches a surface acoustic wave to a pair of identical but inverted output IDTs that form the differential, balanced output signals.

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**Differential Surface Acoustic Wave Filter Having Balanced Outputs****BACKGROUND OF THE INVENTION****1. Technical Field**

5        This invention is related to the field of surface acoustic wave ("SAW") filters. In particular, the invention is related to SAW filters that are useful in UHF radio transceivers, either fixed or mobile, that require frequency selectivity and image rejection in the transceiver front-end prior to a differential mixer. However, the teachings of this invention are applicable to any type of electronic  
10    circuit that employs a SAW filter having balanced outputs or inputs as the case may be.

**2. Description of the Related Art**

Dual-mode leaky SAW structures were reported in the literature by Morita in 1992 (T. Morita, Y. Watanabe, M. Tanaka and Y. Nakazawa, "Wideband Low  
15    Loss Double Mode SAW filters," Proc. 1992 IEEE Ultrasonics Symp., Oct. 20-23) The layout of this type of SAW consists of a central inter-digital transducer ("IDT") surrounded by two other IDTs connected in parallel with a external connection. On either end of the IDTs are reflectors. This resonator structure is usually then cascaded with another identical device to produce a filter with  
20    reasonably good attributes. Usual operation of this filter is to have a single input

and a single output. In other words, these SAW devices do not provide a differential output signal.

Recently, the trend has been to design the front-end of a radio transceiver with a differential input to the first mixer. The advantage of this type of design is to take advantage of the common mode rejection between the two differential inputs. This method then requires a differential SAW filter before the first mixer. Such a differential SAW filter is shown in Figure 1, described in more detail below. As with most such differential SAWs, the structure shown in Figure 1 suffers from an imbalance of the differential outputs. Figures 2 and 3 depict the imbalance in the differential outputs in this type of SAW. This imbalance is due to the non-symmetrical coupling within the IDTs of the output stage.

Therefore, there remains a general need in this field for a differential SAW filter having a pair of balanced outputs.

## SUMMARY OF THE INVENTION

The present invention overcomes the problems noted above and satisfies the needs in this field for a differential SAW filter having a pair of balanced outputs. More specifically, the present invention provides a differential SAW filter having a cascaded structure including at least an input SAW stage and an output SAW stage. The SAW stages are configured so that the electrical distance of travel of the surface acoustic waves from a single unbalanced input of the input

stage to the dual balanced outputs of the output stage is electrically equidistant, thus resulting in a balanced differential output.

For brevity of discussion, the description of the invention is directed primarily to a cascaded structure receiving a single input and outputting two  
5 balanced signals. It is to be understood, however, the invention is not limited to this particular use. The invention would work just as well in an environment calling for a structure receiving two balanced signals and outputting an unbalanced single output.

In the invention, the input stage includes an unbalanced input coupled to a  
10 pair of outer IDTs, both of which launch a surface acoustic wave to an input stage inner IDT. The input stage inner IDT connects to the inner IDT of the output SAW stage, which launches a surface acoustic wave to a pair of output IDTs, referred as the first and second outer output IDTs respectively, that form the differential, balanced output signals.

15 In a preferred embodiment of the invention, in the input stage, the distances between the pair of outer IDTs and the inner IDT are preferably the same, and the distances between the pair of outer IDTs and their respective reflectors are the same. In the output stage, the distances between the inner IDT and the pair of outer output IDTs are not necessarily the same. Further, the  
20 distances between the pair of outer output IDTs and the reflectors adjacent thereto are not necessarily the same. Preferably, each of the output IDTs in the output

stage has the same number of interdigital elements. In the output stage, preferably, two particular distances are predetermined to properly balance the filter. In this preferred embodiment, a distance, defined as  $S_o$ , between the first outer IDT and the input stage inner IDT is predetermined so as to produce a 180  
5 degree phase shift between first and second output signals and a distance, defined as  $R_o$ , between the first outer IDT and an adjacent reflector is predetermined with the cumulative effect of  $R_o$  and  $S_o$  producing an effective integer number of quarter wave lengths for the output stage. The values of  $R_o$  and  $S_o$  would vary depending on the particular structural scheme of the filter.

10 The present invention provides many advantages over presently known SAW filters. Foremost of these advantages is the ability to provide a balanced differential output. A secondary advantage of providing this type of balanced output is that the common mode rejection of the filter is increased, thus providing better noise immunity. This is particularly important when the filter is coupled to  
15 subsequent amplification or other processing stages, whose performance depends upon a truly balanced output stage. Another advantage of the present invention is that having the outer IDTs, in the input stage, as inputs in parallel allows for higher input powers to be used in the differential SAW.

These are just a few of the many advantages of the present invention, as  
20 described in more detail below. As will be appreciated, the invention is capable of other and different embodiments, and its several details are capable of

modifications in various respects, all without departing from the spirit of the invention. Accordingly, the drawings and description of the preferred embodiments set forth below are to be regarded as illustrative in nature and not restrictive.

5

### BRIEF DESCRIPTION OF THE DRAWINGS

The present invention satisfies the needs noted above as will become apparent from the following description when read in conjunction with the accompanying drawings wherein:

FIG. 1 is a layout diagram of a prior art cascaded SAW filter having a pair  
10 of differential outputs that are not balanced;

FIG. 2 is a plot showing the measured wideband response of the prior art SAW filter of FIG. 1;

FIG. 3 is a plot showing the narrowband response of the same filter;

FIG. 4 is a layout diagram of the inventive cascaded SAW filter having  
15 balanced differential outputs;

FIG. 5 is a plot showing the simulated wideband response of the inventive filter shown in FIG. 4;

FIG. 6 is a plot showing the simulated narrowband response of the inventive filter shown in FIG. 4;

FIG. 7 is a partial schematic of the invention incorporated into a wireless  
20 communications device;

FIG. 8 is an illustrative view of two IDTs, a reflector and their respective reference axes therebetween; and,

FIG. 9 is a layout diagram of another embodiment of the inventive cascaded SAW filter having balanced differential outputs.

5

#### DETAILED DESCRIPTION OF THE DRAWINGS

Referring now to the drawings, Figure 1 sets forth a prior art differential SAW filter 10 including a cascaded input SAW stage 16 coupled to an output SAW stage 18. The input SAW stage 16 includes an unbalanced input terminal 10 12 connected to an inner IDT 21. For the purposes of the following description, an IDT comprises both an upper and lower side, where each side has a plurality of interdigital fingers or elements. The definition of IDT is to be construed to also include those IDTs that have an equal number of elements on their upper and lower sides and those IDTs that do not. In most instances, an IDT will have one 15 side grounded, while the other side will be so-called 'hot' or electrically connected. As shown in Figure 1, the inner IDT 21 includes a hot upper six element side and a corresponding grounded lower five element side. Also included in the input SAW stage 16 are two outer coupling IDTs 22, 24 and two reflectors 20. The outer coupling IDTs 22, 24 are connected to a pair of outer 20 input IDTs 38, 40 of the output SAW stage 18. In addition to these outer input IDTs 38, 40, the output SAW stage 18 includes two reflectors 20, and one inner



output IDT 14 having two outputs 14A, and 14B, which form the differential output of the filter 10.

Several “gaps” are defined with respect to reference axes between the various IDTs and reflectors as illustrated in Figure 8. The reference axes are typically each  $\lambda_0/8$  in width. The gap spacings are important to understand why the prior art filter 10 is unbalanced. In the input SAW stage 16, four gaps are defined, Gap R (referred to also as “dg” in the art) 26, 32 and Gap S (referred to also as “dt” in the art) 28, 30. Gap R describes the distance between the pair of outer coupling IDTs 22, 24 and the reflectors 20, and Gap S describes the distance between the inner IDT 21 and the pair of outer coupling IDTs 22, 24. In the output SAW stage 18, similar gap spacings are defined. Here, Gap R 42, 48 describes the distance between the pair of outer input IDTs 38, 40 and the reflectors 20, and Gap S 44, 46 describes the distance between the inner output IDT 14 and the pair of outer input IDTs 38, 40.

Operationally, the prior art SAW 10 functions as follows. An input electrical signal to the unbalanced input 12 is electrically coupled to the inner IDT 21, which, according to the well-known principles of SAW devices, converts the electrical signal to a mechanical wave (or surface acoustic wave) that propagates out from both ends of the inner IDT 21. This surface acoustic wave then propagates to the pair of outer coupling IDTs 22, 24, which, in a converse manner, convert the mechanical wave into an electrical signal. But some of the

surface acoustic wave passes beyond the outer coupling IDTs **22, 24** and hits the reflectors **20**, which bounce the wave back towards the inner IDT **21**. This creates a resonance within the space defined between the two reflectors **20**, thereby creating a sort of resonant cavity.

5        The electrical signal from the outer coupling IDTs **22, 24** is then fed to the two outer input IDTs **38, 40** of the output SAW stage **18**. The outer input IDTs **38, 40** then convert the electrical signal back into a surface acoustic wave in the same manner as described above. A second resonant cavity is then formed between the two reflectors **20** of the output SAW stage **18**. The formed surface  
10    acoustic waves impact the inner output IDT **14**, which then convert the waves into two differential electrical signals **14A** and **14B**. Turning now to the gap spacings, in the input SAW stage **16**, Gap R **26** is equal to Gap R **32**, and Gap S **28** is equal to Gap S **30**. There is a symmetry in the spacings, which results in balanced signals being transferred to the two outer coupling IDTs **22, 24**. In the output  
15    SAW stage **18**, however, although Gap R **42** and Gap R **48** are equal, the Gap S distances **44, 46** are slightly different depending upon which side of the inner output IDT **14** they are referenced to. As shown in Figure 1, output **14A** derives its signal from the upper five element side of inner output IDT **14**. In contrast, output **14B** derives its signal from the lower six element side of inner output IDT  
20    **14**. Thus, the Gap S spacings, **46, 46**, on either side of the inner output IDT **14** is shorter for output **14B** and longer for output **14A**. This asymmetry in the

mechanical path of the surface acoustic waves results in an imbalance in the differential output stage, as shown in Figures 2 and 3.

Figure 2 sets forth a plot **50** showing the measured wideband response of the prior art SAW filter of Figure 1. Plot **54** shows the response measured at output terminal 2 **14B**, and plot **52** shows the response measured at output terminal 1 **14A**. This plot shows that the response at the two outputs **14A**, **14B** is different in the pass band (between about 865 and 902 MHz), as shown in more detail in Figure 3, and is also very different in the stop band beyond the pass band (around 1000 MHz). Thus, the circuit is particularly unbalanced in this frequency region beyond the filter pass band. It is to be understood that the present invention would work in other frequency bands as well. The frequencies set out in the description are for illustrative purposes only.

Figure 3 is a plot **60** showing the narrowband response of the same filter **10**. As seen in this plot, there is a noticeable difference in the measurements **52**, **54** at the two output terminals in the lower part of the pass band, between about 865 and 892 MHz. As described above, this imbalance in the output terminals is undesirable, particularly within the filter's pass band.

Turning now to the present invention, Figure 4 is a preferred layout diagram of the inventive cascaded SAW filter **70** having balanced differential outputs. This filter **70** includes an input SAW stage **76** cascaded to an output SAW stage **78**. The input SAW stage **76** includes an unbalanced input **72** coupled

in parallel to a pair of outer IDTs **82, 84**, and a single input stage inner IDT **86**. The input stage inner IDT **86** connects the input SAW stage **76** to the output SAW stage **78**. The output SAW stage includes an inner IDT **90** connected to the input stage inner IDT **86** of the input SAW stage **76**, and a pair of outer output IDTs **74, 75** producing balanced outputs **74A** and **75A** respectively. The outer output IDTs **74, 75** are inverted relative to each other. Also included in both the input SAW stage **76** and the output SAW stage **78** are pairs of reflectors **80** for setting up the resonant surface acoustic wave within each stage. The preferred layout has the output stage mirrored to the layout of the input stage with the exception of the outer output IDT **74** being inverted.

As with the prior art device, there are certain gap distances that effect the performance of the filter. Turning first to the input SAW stage **76**, Gap **R 92, 98** describes the distance between the outer IDTs **82** and the reflectors **80**. Gap **S 94, 96** describes the distance between the pair of outer IDTs **82** and the input stage inner IDT **86**. For the output SAW stage **78**, Gap **Ro, 100**, describes the distance between the outer output IDT **74** and the reflector **80** adjacent thereto, and Gap **So, 102**, describes the distance between the inner IDT **90** and the outer output IDT **74**. Gap **R 106** describes the distance between the outer output IDT **75** and the reflector **80** adjacent thereto. Gap **S 104** describes the distance between outer output IDT **75** and the inner IDT **90**. In the preferred embodiment of the present invention, Gap **S 94, 96** of the input stage and Gap **S 104** of the output stage are

equal, and Gap R 92, 98 of the input stage and Gap R 106 of the output stage are equal. However, as will be described below, Gap So 102 and Gap Ro 100 are not necessarily equal to Gap S and Gap R respectively.

Operationally, the filter 70 in Figure 4 functions similarly to that shown in Figure 1. An electrical signal on the unbalanced input 72 is electrically coupled to the pair of outer IDTs 82 which launch the mechanical surface acoustic wave into the resonant cavity bounded by the two reflectors. The established waves are coupled to the input stage inner IDT 86 and converted into an electrical signal. This signal is then connected to the inner IDT 90 of the output SAW stage 78. This inner IDT 90 then launches a mechanical surface acoustic wave into the resonant cavity bounded by the two reflectors 80 of the output SAW stage 78. This wave is received by the two balanced outer output IDTs 74, 75, which then convert the wave into balanced electrical signals, 74A, 75A respectively.

The inventive SAW shown in Figure 4 is balanced because there is electrical symmetry in terms of what electrical lengths the outer output IDTs 74, 75 see – electrical symmetry that is missing in the prior art circuits. In the prior art, the gap sizes in the input stage are symmetrical, and so are the gaps in the output stage. However, the electrical length seen by the five element side of inner output IDT 14 is not the same electrical length seen by the six element side of inner output IDT 14. This is not the case in the present invention. In the present invention, despite the fact that the physical distances defined by Gaps Ro

and  $S_o$  may be different from Gaps R and S of the output stage, respectively, the unique physical layout of the filter allows the three element side of outer output IDT 74 to see the same electrical length as the three element side of outer output IDT 75. This is partly achieved by the outer output IDTs being inverted to one another. In contrast, the prior art circuits have equal distances for each Gap S, and each Gap R respectively. The prior art circuits were also characterized by output signals deriving from the side of an IDT having a different number of interdigital elements. This resulted in the effective gap spacing defined by Gaps S 44, 46 being different for the upper and lower sides of the inner output IDT 14. In the present invention, however, this discrepancy dilemma has been resolved. In the present invention, both outer output IDTs 74, 75 have the same number of identical interdigital elements, but the outer output IDTs are not necessarily physically spaced equidistant from the output stage inner IDT 90.

In the input stage of the present invention, the size of Gaps R 92, 98, S 94, 96, and the number of interdigital elements of the inner and outer IDTs must be suitably chosen so as to provide an effective integer number of quarter wave lengths. Likewise, in the output stage, the size of Gaps  $R_o$ ,  $S_o$ , R and S, and the number of interdigital elements of the inner and outer IDTs must be suitably chosen so as to provide for an effective integer number of quarter wave lengths. Of course, the integer value of the output stage may be different from that of the input stage depending on the selection of  $R_o$  and  $S_o$ . It is to be understood that,

in the output stage, the collective effect of the number of interdigital elements of the output stage inner IDT 90 and the sizes of Gaps So 102 and S 104 play an important role in producing a 180 degree phase shift in the output signals. However, in the preferred embodiment of the present invention, the size of Gap S 104 in the output stage is fixed to the value of Gap S 94 in the input stage; the value of Gap R 106 in the output stage is fixed to the value of Gap R 98 in the input stage; the number of elements of the output stage inner IDT 90 is fixed to the same number found in the input stage inner IDT 86; and, the number of elements of the outer output IDTs 74, 75 is the same number found in the outer IDTs 82. This configuration is done so as to minimize impedance issues. Hence, in the preferred embodiment of the invention the sizes of only Gaps So and Ro are to be suitably selected depending on the particular configuration of the filter. In particular, the size of Gap So is selected so as to ideally produce the 180 degree phase shift in the two outputs 74A, 75A and at the same time, the size of Ro is selected so as to have the cumulative effect of Gap Ro and Gap So produce an effective integer number of quarter wave lengths for the output stage. Although the description is primarily directed to Gaps So 102 and Ro 100 as preferably being the two gaps adjusted for a particular structural filter layout, it is to be understood that it is possible and within the scope of the invention to have any gap spacing in the output stage to be designated as the gap spacing to be adjusted. With this in mind, all the Gaps 100, 102, 104, 106 of the output stage could very

well be suitably adjusted so as to produce the effective integer number of quarter wave lengths in the output stage and to produce a 180 degree phase shift between the two outputs. Gaps  $S_o$  and  $R_o$  could be thought of as “shims” placed into the Gaps 100, 102, 104, 106. However, this approach has proven, at present, to be impractical.

The circuit of Figure 4 was electrically modeled using in part, the Three-Port Admittance Matrix method for an IDT. Within this model a feed-through component was also established to represent the extra length of bonding or connecting wire for Output 1 74A. Figures 5 and 6 illustrate the theoretical response of the circuit shown in Figure 4. Note that when comparing to Figure 2 and 3, there is a significant reduction in the difference between the two outputs, particularly in the pass band of the filter. The following particulars were used in modeling the circuit. In both stages, the outer IDTs each has ten interdigital elements on the upper side, and nine elements on the other side. The inner IDTs each have thirteen elements on the upper side, and fourteen elements on the other side. Gaps  $R$  and  $R_o$  were defined as  $0\lambda$  (with respect to the reference axes). Gap  $S$  was defined as  $0.75\lambda$ . Gap  $S_o$  was defined as  $0.25\lambda$ .

Figure 5 is a plot 110 showing the simulated wideband response of the inventive filter shown in Figure 4, and Figure 6 is the corresponding plot 120 showing the simulated narrowband response. As seen in these plots, there is much less difference between the performance of output 1 74A, plotted as 112,



and output 2 **74B**, plotted as **114**. This is particular so in the pass band shown in Figure 6, where the response is almost identical. It is believed that the slight difference in response is due to the feed-through component added to the model.

Although the present invention has been described in terms of an  
5 environment having a single unbalanced input and requiring two balanced outputs, it is be understood that the present invention could work in a reversed environment. The present invention would work effectively where the environment called for two unbalanced inputs and a single balanced output.

Figure 7 illustrates on a partial schematic level how the invention would  
10 be incorporated into a wireless communications device at the receive end. Before the differential SAW device **70** there is shown an antenna means including: an antenna **200** communicating to a first unbalanced filter **210**, and a low noise amplifier **220**. Located down from the differential SAW device **70** is a communications circuit means comprising a balanced mixer **230**, an intermediate  
15 frequency **250** and a local oscillator **240**.

It will be appreciated that the above description relates to the preferred embodiment by way of example only. Many variations on the invention will be obvious to those knowledgeable in the field, and such obvious variations are within the scope of the invention as described and claimed, whether or not  
20 expressly described. Figure 9 is one such example of another embodiment of the present invention.

For example, the outer output IDTs in the preferred embodiment have been described and illustrated with three interdigital elements on the upper side and two interdigital elements on the lower side. It is understood that the invention in no way is limited to this configuration of the outer output IDTs. A change in  
5 the structural makeup of the outer output IDTs would need to be suitably adjusted for by adjusting the  $S_o$  and  $R_o$  gap distances as described above.

As an additional example of another embodiment of the present invention, it is envisioned that a two IDT structure for the input stage may be possible.

I claim:

1. A differential surface acoustic wave (SAW) filter comprising:
  - (a) an input filter stage for receiving an unbalanced electric signal and  
5 filtering such signal into a conditioned electric signal; and,
  - (b) an output filter stage for receiving the conditioned electric signal via an output stage inner interdigital transducer (IDT), the output stage inner IDT converting the conditioned electric signal into an acoustic wave and producing balanced first and second differential output signals via,  
10 respectively, first and second outer output IDTs, the first and second outer output IDTs being identical but inverted relative to the other.
2. A differential SAW filter as claimed in claim 1, wherein the output stage has the output stage inner IDT electrically coupled to the input stage, wherein the  
15 first outer output IDT and a first reflector adjacent thereto are positioned at a first end of the output stage inner IDT, and wherein the second outer output IDT and a second reflector adjacent thereto are positioned at a second end of the output stage inner IDT.
- 20 3. A differential SAW filter as claimed in claim 2, wherein a distance, defined as So, between the first outer output IDT and the output stage inner IDT is

predetermined so as to produce a 180 degree phase shift between the first and second output signals.

4. A differential SAW filter as claimed in claim 3, wherein a distance, defined as  
5         $R_o$ , between the first outer output IDT and the adjacent reflector thereto is  
predetermined with the cumulative effect of  $R_o$  and  $S_o$  producing an effective  
integer number of quarter wave lengths for the output stage.
5. A differential SAW filter as claimed in claim 4, wherein the input stage has an  
10        input stage inner IDT, a first outer IDT, a second outer IDT and at each end of  
the input stage a reflector positioned adjacent to such outer IDTs.
6. A differential SAW filter as claimed in claim 5, wherein a distance, defined as  
       $S$ , between the input stage inner IDT and the first outer IDT is the same  
15        distance between the input stage inner IDT and the second outer IDT.
7. A differential SAW filter as claimed in claim 6, wherein a distance, defined as  
       $R$ , between the first outer IDT and the reflector adjacent thereto is the same  
distance between the second outer IDT and the reflector adjacent thereto.

8. A differential SAW filter as claimed in claim 7, wherein the output stage is further characterized by a distance between the second outer output IDT and the output stage inner IDT is the same distance as S
- 5 9. A differential SAW filter as claimed in claim 8, wherein the output stage is further characterized by a distance between the second outer output IDT and the adjacent reflector is the same distance as R.
- 10 10. A differential SAW filter as claimed in claim 9, wherein  $R_0$  is  $0\lambda$ ,  $S_0$  is  $0.25\lambda$ ,  $R$  is  $0\lambda$ ,  $S$  is  $0.75\lambda$ , the outer IDTs of both stages each have ten elements on one side and nine elements on the other side, and the inner IDTs of both stages each have thirteen elements on one side and fourteen elements on the other side.
- 15 11. A wireless communications device comprising:
- (a) an antenna;
  - (b) communications circuitry; and,
  - (c) at least one multistage differential surface acoustic wave (SAW) filter characterized by:
- 20 an input filter stage for receiving an unbalanced electric signal and filtering such signal into a conditioned electric signal; and,

an output filter stage for receiving the conditioned electric signal via an output stage inner interdigital transducer (IDT), the output stage inner IDT converting the conditioned electric signal into an acoustic wave and producing balanced first and second differential output signals via, respectively, first and second outer output IDTs, the first and second outer output IDTs being identical but inverted relative to the other;

wherein the differential SAW filter cooperatively functions between the antenna and the communications circuitry.

12. A wireless device as claimed in claim 11, wherein the communications circuitry includes a receiver.

13. A wireless device as claimed in claim 12, wherein the communications circuitry includes a transmitter.

14. A differential surface acoustic wave filter comprising:

- (a) a first stage for receiving two balanced electric signals via, respectively, a first and second interdigital transducer (IDT), such IDTs being identical but inverted relative to the other and filtering the balanced electric signals into a single unbalanced electric signal; and,

(b) a second stage for receiving the single unbalanced electric signal and filtering such signal into a further unbalanced electric output signal.

15. A differential SAW filter as claimed in claim 14, wherein the first stage has  
5 the first stage inner IDT electrically coupled to the second stage, wherein the first outer input IDT and a first reflector adjacent thereto are positioned at a first end of the first stage inner IDT, and wherein the second outer input IDT and a second reflector adjacent thereto are positioned at a second end of the first stage inner IDT.

10

16. A differential SAW filter as claimed in claim 15, wherein a distance, defined as  $S_o$ , between the first outer input IDT and the first stage inner IDT is predetermined so as to produce a 180 degree phase shift between input signals.

15

17. A differential SAW filter as claimed in claim 16, wherein a distance, defined as  $R_o$ , between the first outer input IDT and the adjacent reflector thereto is predetermined with the cumulative effect of  $R_o$  and  $S_o$  producing an effective integer number of quarter wave lengths for the first stage.

20

18. A differential SAW filter as claimed in claim 17, wherein the second stage has  
a second stage inner IDT, a first outer IDT, a second outer IDT and at each  
end of the input stage a reflector positioned adjacent to such outer IDTs.
- 5 19. A differential SAW filter as claimed in claim 18, wherein a distance, defined  
as S, between the second stage inner IDT and the first outer IDT is the same  
distance between the second stage inner IDT and the second outer IDT.
20. A differential SAW filter as claimed in claim 19, wherein a distance, defined  
10 as R, between the first outer IDT and the reflector adjacent thereto is the same  
distance between the second outer IDT and the reflector adjacent thereto.
21. A differential SAW filter as claimed in claim 20, wherein the first stage is  
further characterized by a distance between the second outer input IDT and  
15 the first stage inner IDT is the same distance as S.
22. A differential SAW filter as claimed in claim 21, wherein the first stage is  
further characterized by a distance between the second outer input IDT and  
the reflector adjacent thereto is the same distance as R.



23. A differential SAW filter as claimed in claim 22, wherein  $R_0$  is  $0\lambda$ ,  $S_0$  is  $0.25\lambda$ ,  $R$  is  $0\lambda$ ,  $S$  is  $0.75\lambda$ , the outer IDTs of both stages each have ten elements on one side and nine elements on the other side, and the inner IDTs of both stages each have thirteen elements on one side and fourteen elements  
5 on the other side.

24. A wireless communications device as claimed in claim 13, further comprising:  
at least one reversed multistage differential surface acoustic wave filter  
characterized by:

10 a first stage for receiving two balanced electric signals via,  
respectively, a first and second interdigital transducer (IDT), such  
IDTs being identical but inverted relative to the other and filtering  
the balanced electric signals into a single unbalanced electric  
signal; and,

15 a second stage for receiving the single unbalanced electric signal and  
filtering such signal into a further unbalanced electric output signal.

25. A wireless communications device comprising:

(a) an antenna;

20 (b) communications circuitry; and,

(c) at least one reversed multistage differential SAW filter characterized by:

a first stage for receiving two balanced electric signals via,  
respectively, a first and second IDT, such IDTs being identical but  
inverted relative to the other and filtering the balanced electric  
signals into a single unbalanced electric signal; and,  
5 a second stage for receiving the single unbalanced electric signal  
and filtering such signal into a further unbalanced electric output  
signal;  
wherein the least one reversed multistage differential SAW filter  
cooperatively functions between the antenna and the  
10 communications circuitry.

26. A wireless communications device as claimed in claim 25, wherein the  
communications circuitry includes a transmitter.
- 15 27. A wireless communications device as claimed in claim 26, wherein the  
communications circuitry includes a receiver.
28. A wireless communications device as claimed in claim 27, wherein at least  
one multistage differential SAW filter characterized by:  
20 an input filter stage for receiving an unbalanced electric signal and  
filtering such signal into a conditioned electric signal; and,

an output filter stage for receiving the conditioned electric signal via an  
output stage inner IDT, the output stage inner IDT converting the  
conditioned electric signal into an acoustic wave and producing balanced  
first and second differential output signals via, respectively, first and  
5 second outer output IDTs, the first and second outer output IDTs being  
identical but inverted relative to the other.

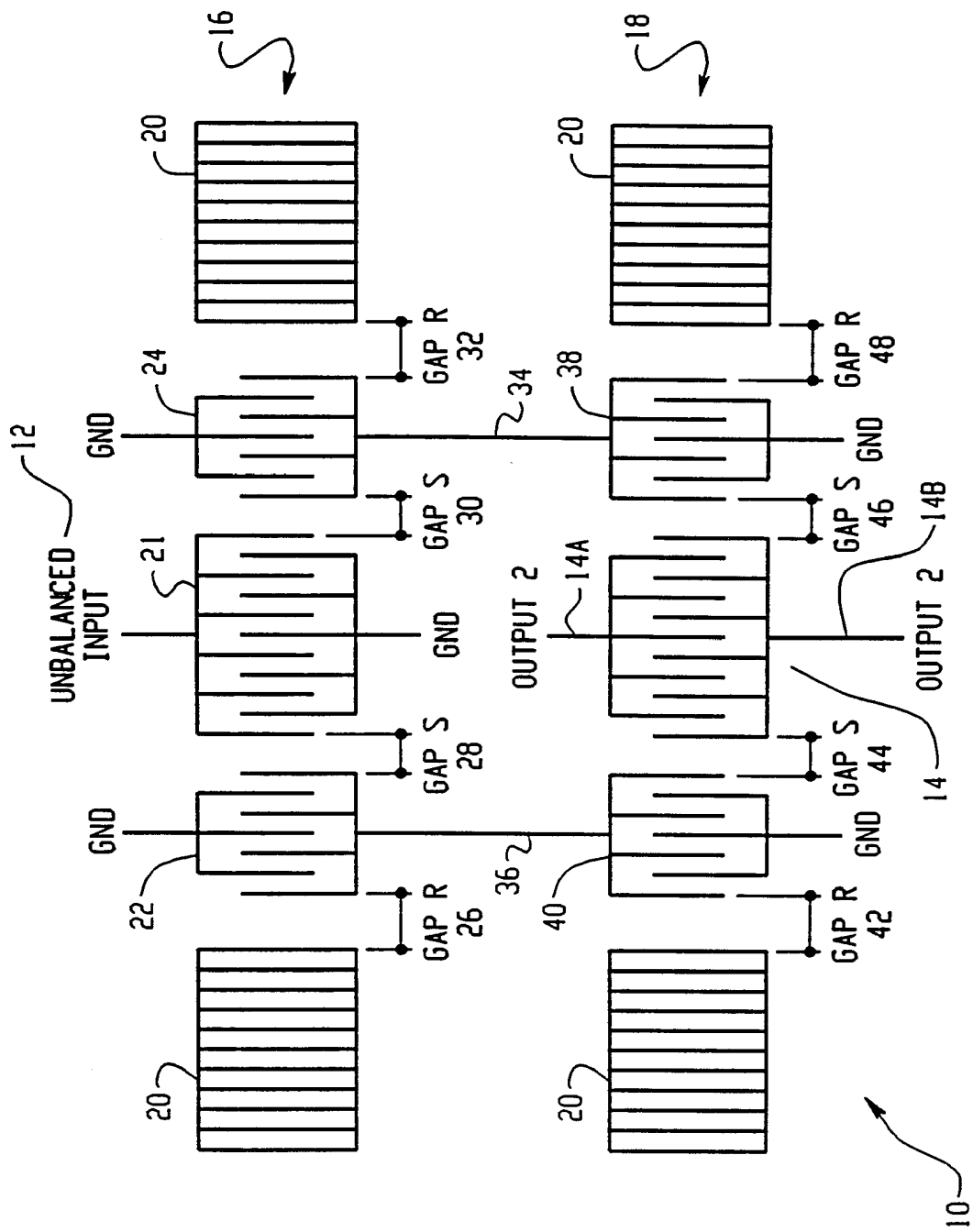
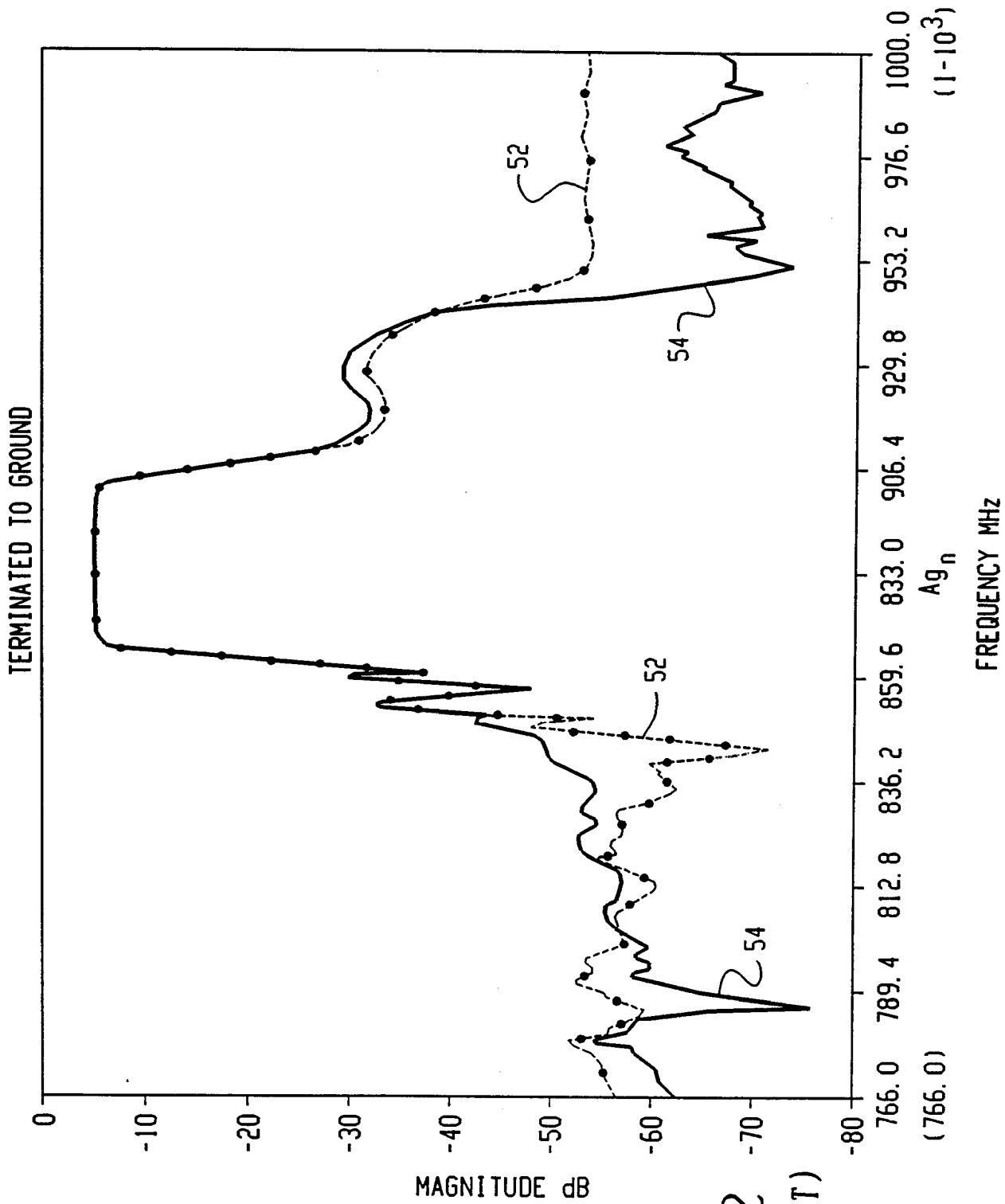


Fig. 1  
(PRIOR ART)



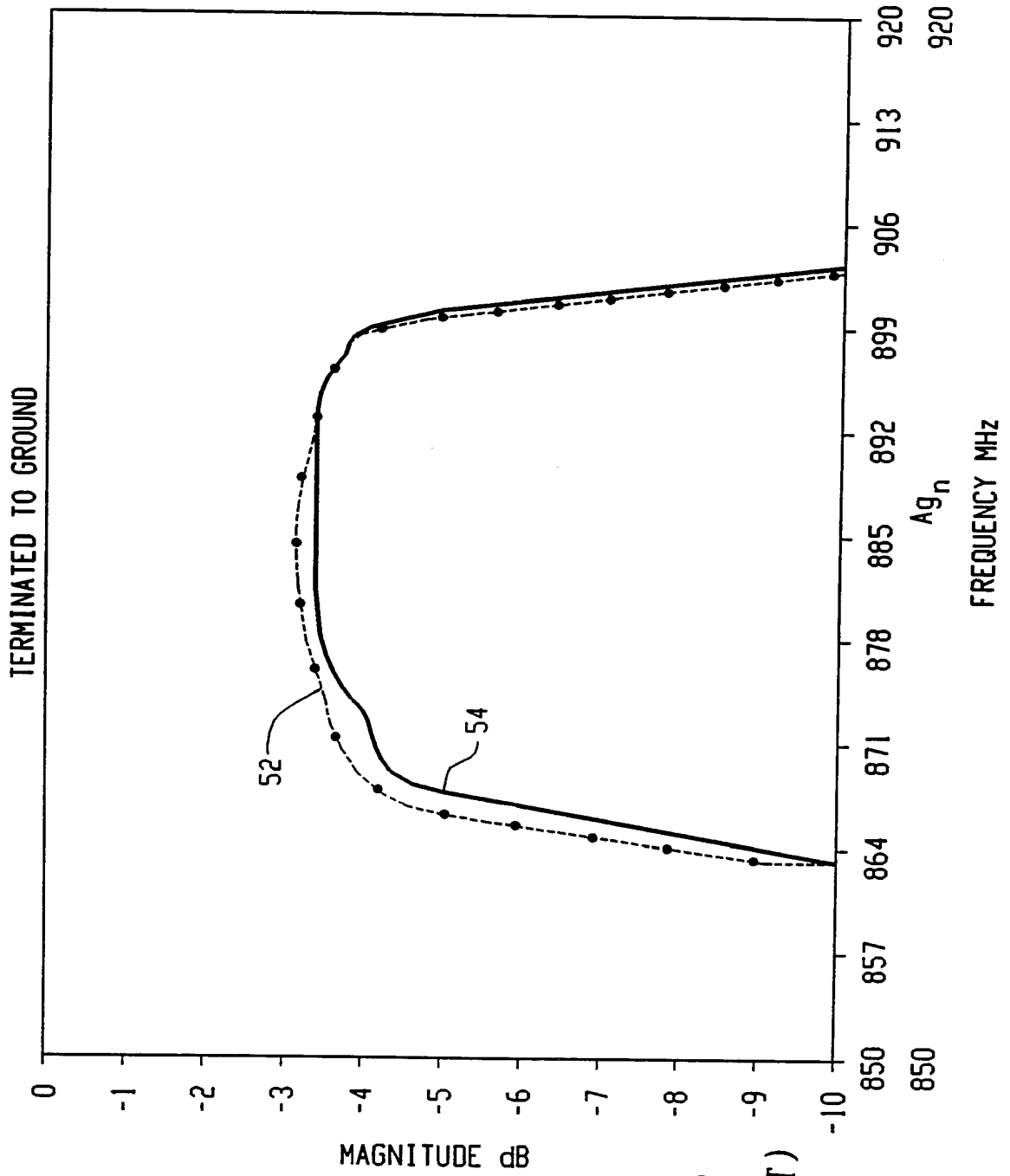


Fig. 3  
(PRIOR ART)

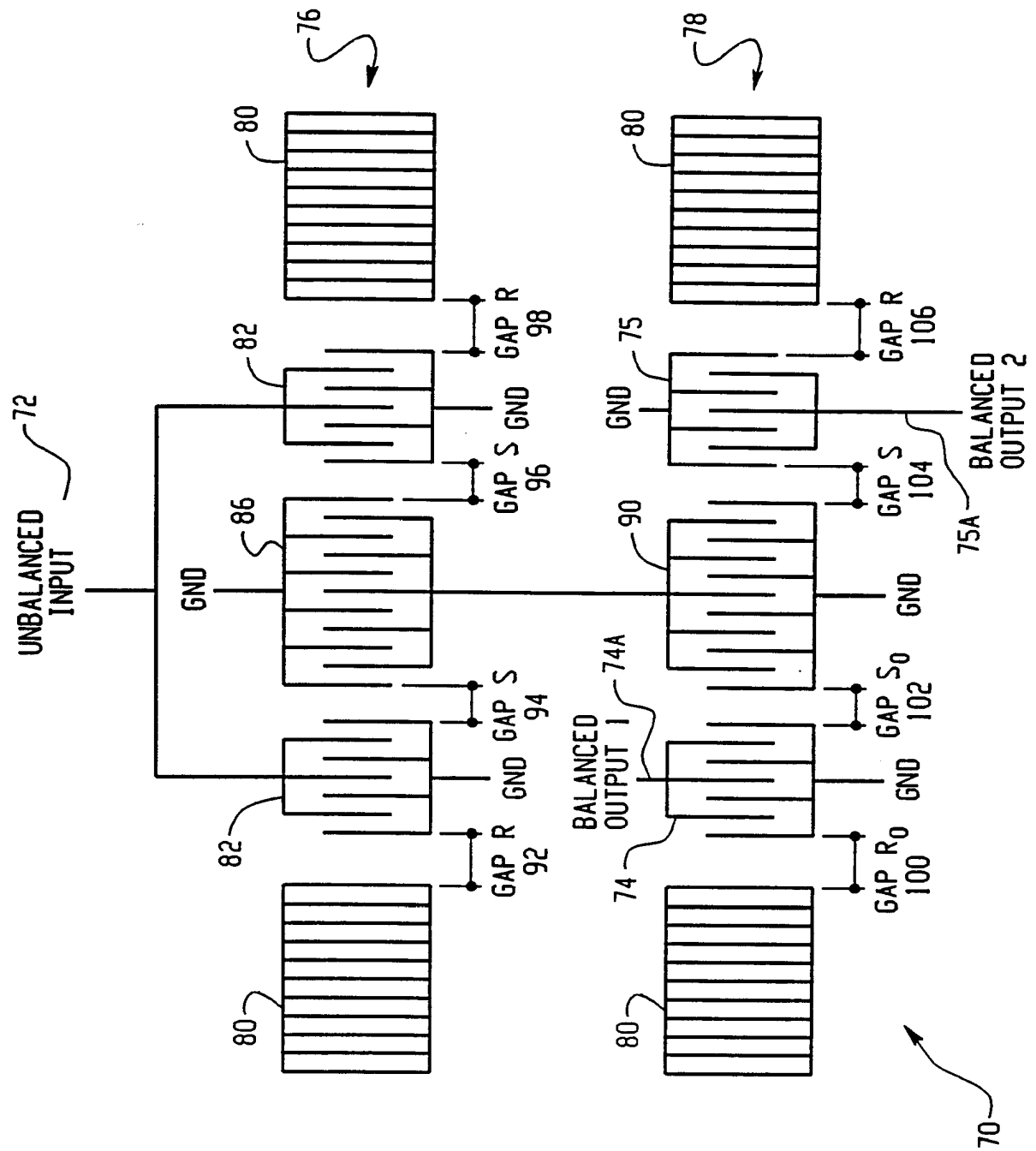


Fig. 4

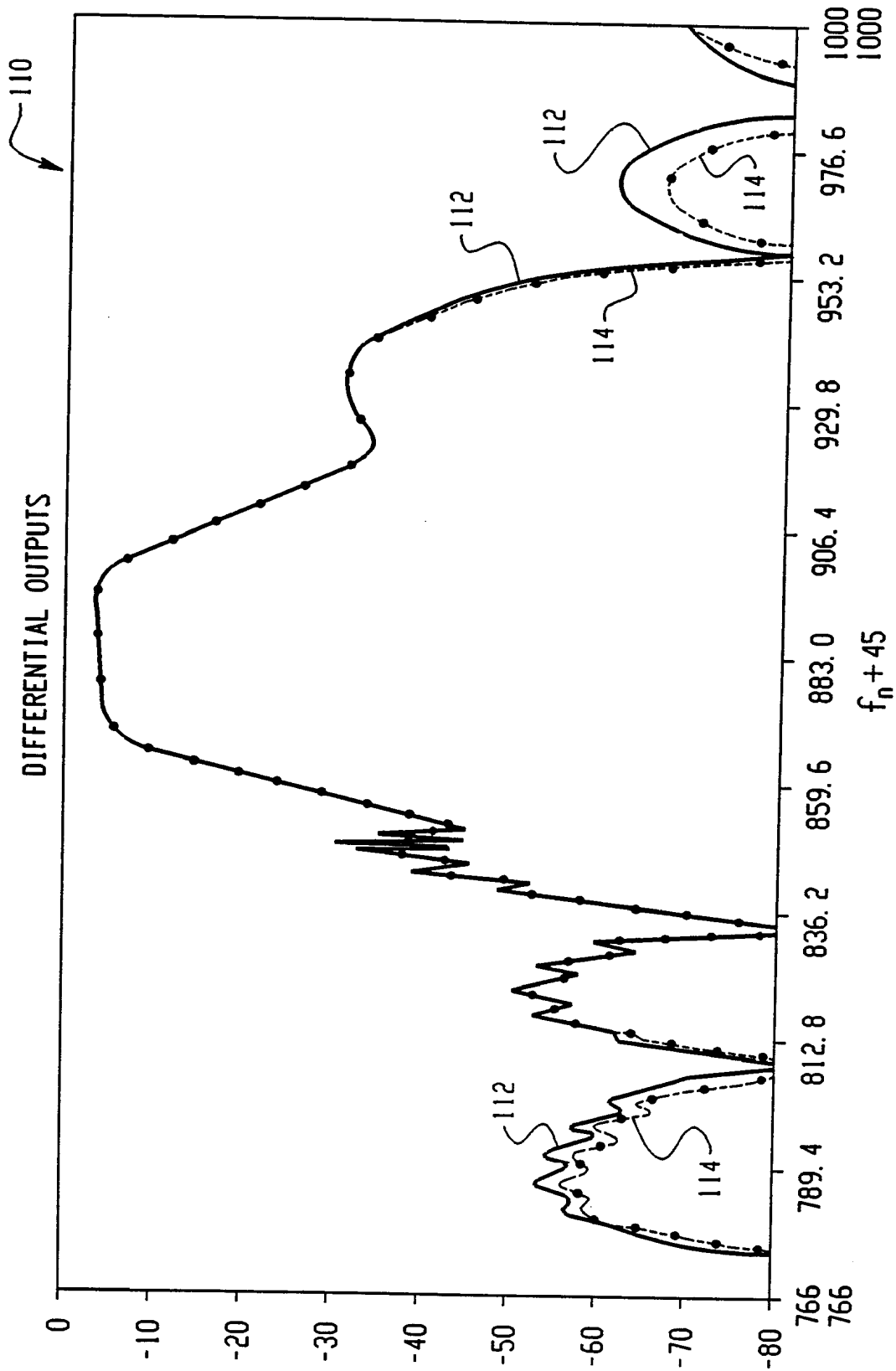


Fig. 5



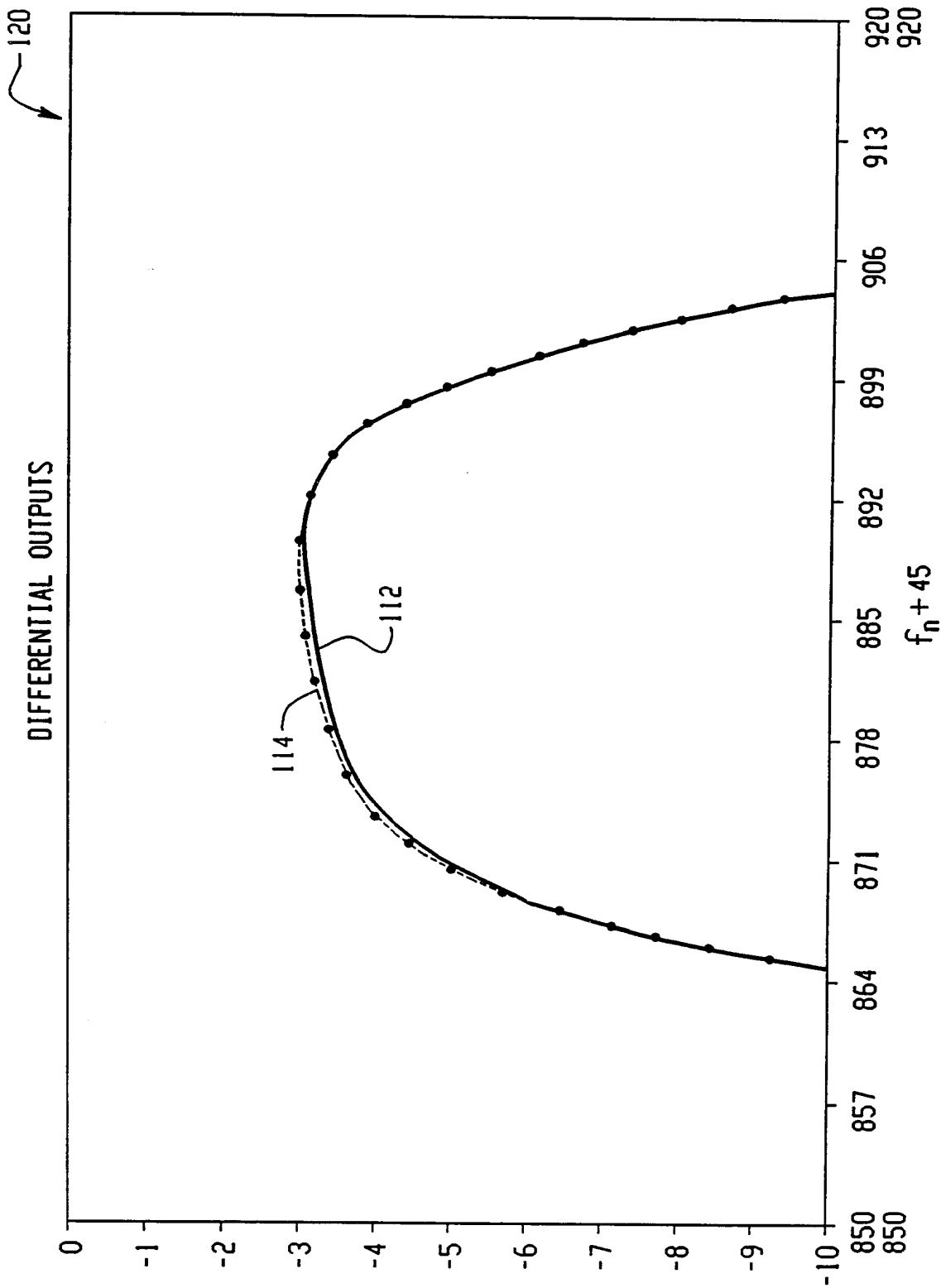


Fig. 6

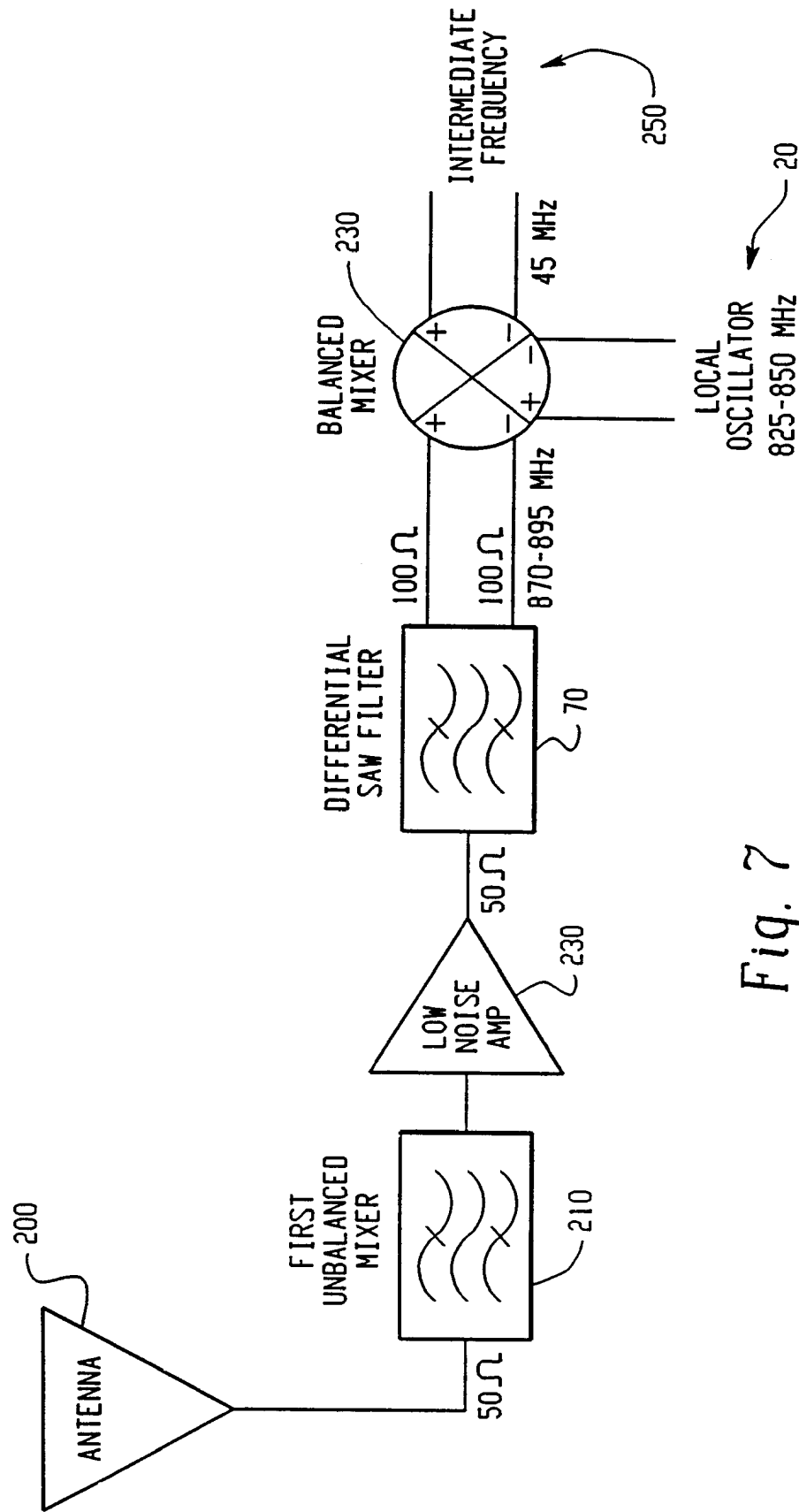


Fig. 7

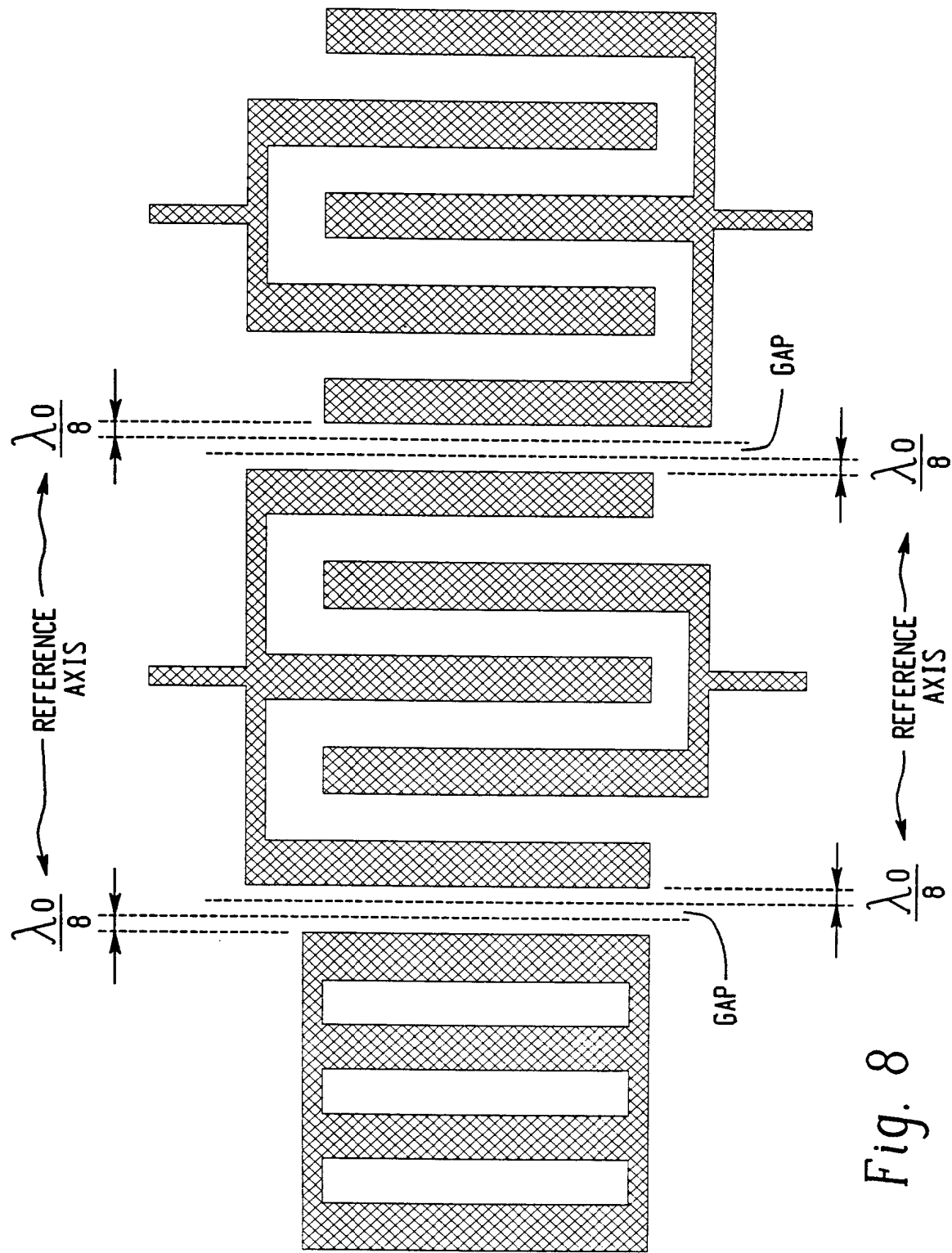


Fig. 8

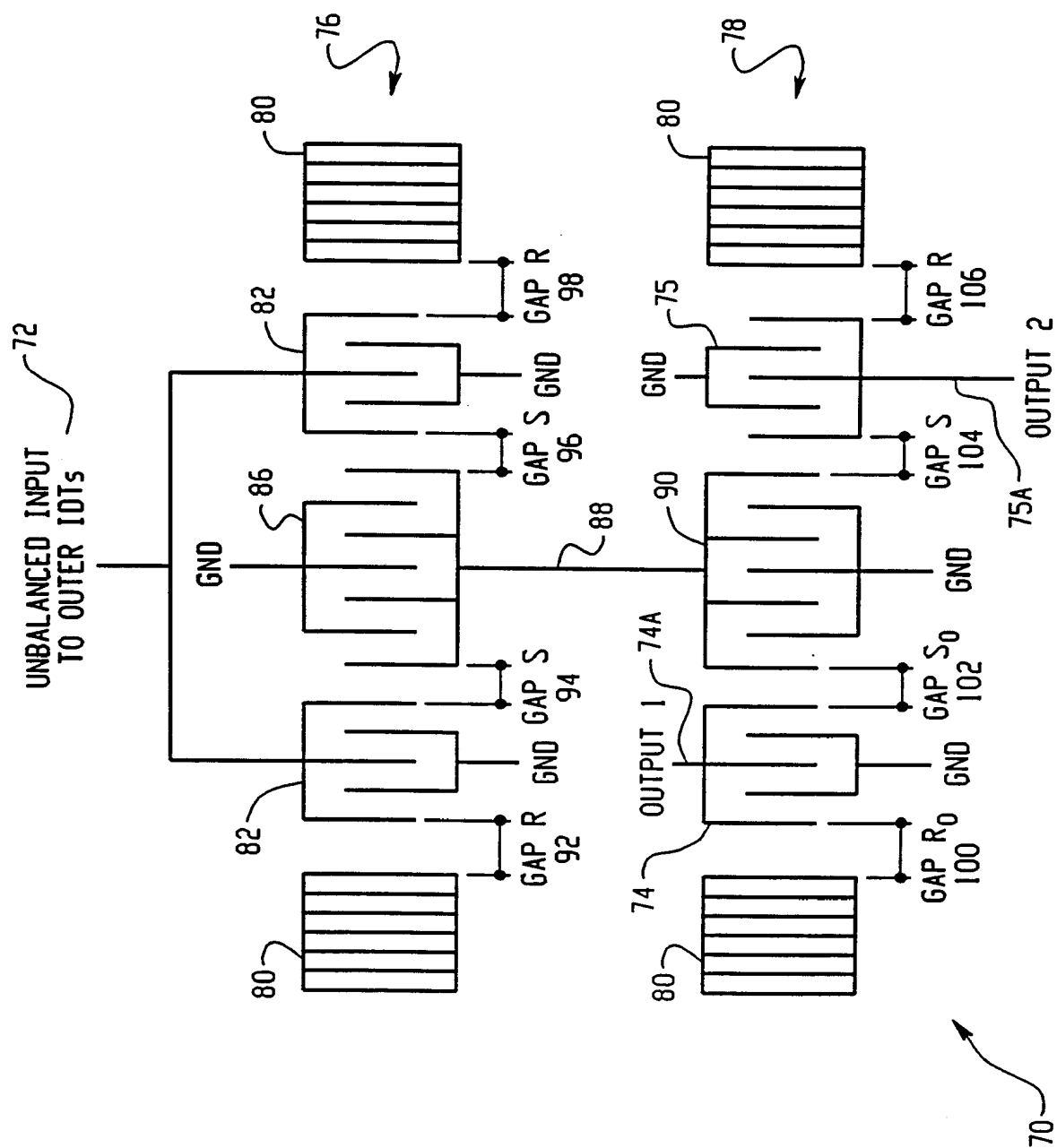


Fig. 9

# INTERNATIONAL SEARCH REPORT

International Application No

PCT/CA 00/00547

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 H03H9/64

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 H03H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EP0-Internal

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 196 38 370 A (SIEMENS MATSUSHITA COMPONENTS) 2 April 1998 (1998-04-02)	1
Y	column 2, line 49 - line 56; figure 4	11
X	EP 0 872 954 A (THOMSON CSF) 21 October 1998 (1998-10-21)	14
Y	column 4, line 52 -column 5, line 20; figure 1	25
	--- -/-	

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

13 September 2000

Date of mailing of the international search report

21/09/2000

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D/L PINTA BALLE., L

## INTERNATIONAL SEARCH REPORT

International Application No

PCT/CA 00/00547

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	ENDOH G ET AL: "HIGH PERFORMANCE BALANCED TYPE SAW FILTERS IN THE RANGE OF 900MHZ AND 1.9GHZ" IEEE ULTRASONICS SYMPOSIUM PROCEEDINGS,US,NEW YORK, NY: IEEE, 5 October 1997 (1997-10-05), pages 41-44, XP000848455 ISBN: 0-7803-4154-6 paragraph '0002! paragraph '0004! figures 1,3	1, 11, 14, 25
X	DE 197 24 258 A (SIEMENS MATSUSHITA COMPONENTS) 10 December 1998 (1998-12-10) column 1, line 8 - line 16	14
Y	column 1, line 48 - line 67 figures 1,2	11, 25
A	US 5 835 990 A (GRATTON CONRAD FRANÇOIS ET AL) 10 November 1998 (1998-11-10)	1, 11, 14
Y	column 2, line 38 -column 3, line 35 column 8, line 38 -column 9, line 13 figures 13,14	25

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/CA 00/00547

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 19638370 A	02-04-1998	WO 9812809 A	26-03-1998
		EP 0927458 A	07-07-1999
		US 6081172 A	27-06-2000
EP 0872954 A	21-10-1998	FR 2762458 A	23-10-1998
		CA 2235058 A	18-10-1998
		CN 1197328 A	28-10-1998
		JP 2957159 B	04-10-1999
		JP 10303683 A	13-11-1998
		US 5936487 A	10-08-1999
DE 19724258 A	10-12-1998	EP 0884843 A	16-12-1998
US 5835990 A	10-11-1998	CA 2178438 A	17-12-1996
		WO 9700556 A	03-01-1997
		US 5790000 A	04-08-1998